Reversal of Long-Term Trends in Ethane Identified from the Global Atmosphere Watch Reactive Gases Measurement Network

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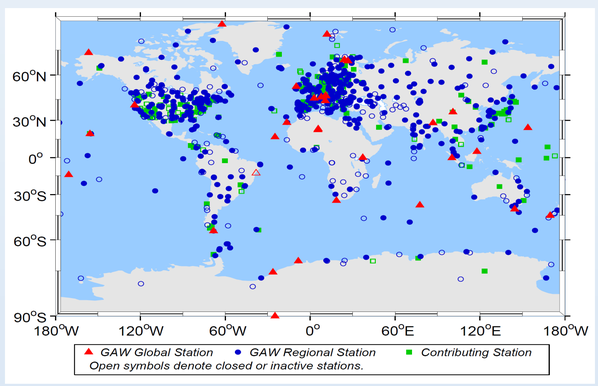
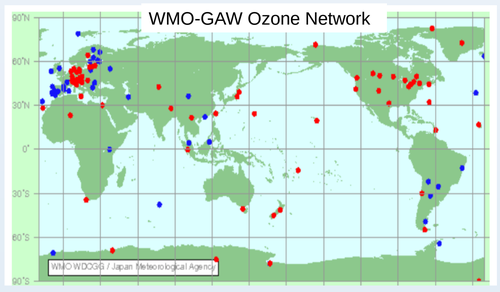
The WMO GAW Reactive Gases Program

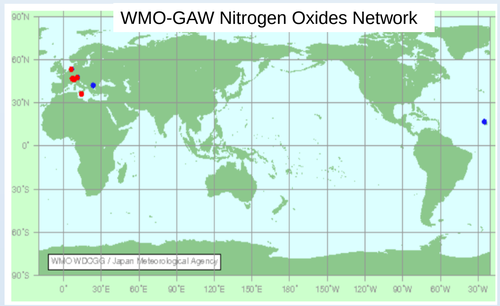
Reactive gases play an important role in climate and air pollution issues. They control the self-cleansing capability of the troposphere, contribute to air pollution and acid deposition, regulate the lifetimes and provide tracers for deciphering sources and sinks for greenhouse gases. Within GAW, the focus is placed on long-term, high-quality observations of ozone (O_3), carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO_x), and sulfur dioxide (SO_2). More than 100 stations worldwide carry out reactive gases measurements with data reported to two World Data Centers. The reactive gases program in GAW cooperates with regional networks and other global monitoring initiatives in order to attain a complete picture of the tropospheric chemical composition. Observations are being made by in-situ monitoring, measurements from commercial routine air-crafts (e.g. IAGOS), column observations, and from flask sampling networks.

Quality control and coordination of measurements between participating stations are a primary emphasis. GAW reactive gases data in rapid delivery mode are used to evaluate operational atmospheric composition forecasts in the EU Copernicus Atmospheric Monitoring Service. Oversight of the program is provided by GAW-WMO coordinated Reactive Gases Scientific Advisory Committee (RG-SAG).

Reactive Gases Network

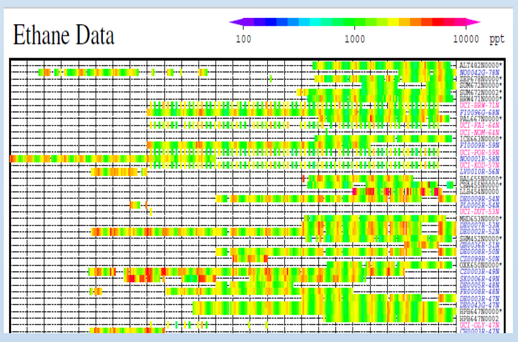


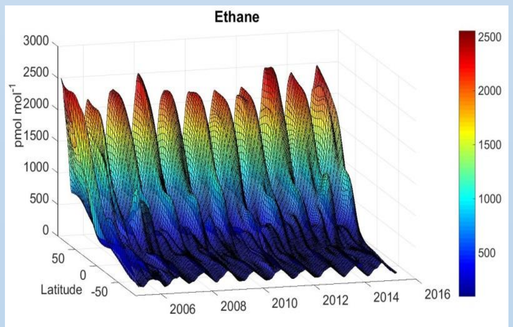


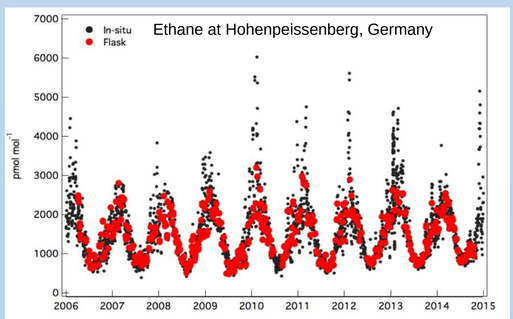


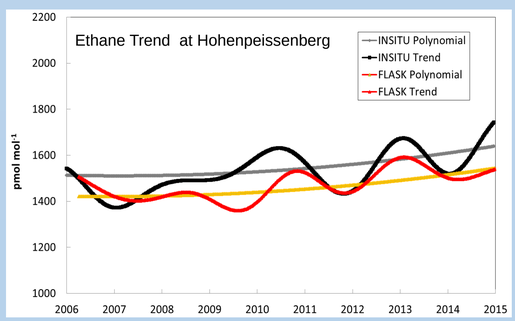
While the GAW-WMO Network includes a vast number of surface stations the coverage of reactive gases measurements varies. Ozone is the most frequently measured species, measured at some 100 global sites, contrasted by nitrogen oxides, which are measured at far fewer locations. These differences in global observations are driven by the historical evolution of the program and by measurements constraints, for example availability and cost of suitable instrumentation, and staff expertise for the monitoring of particular gases.

Products



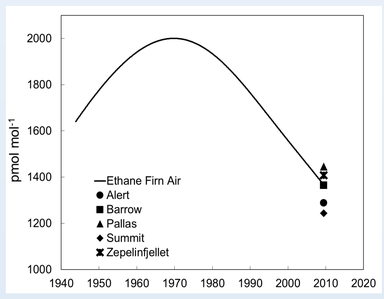


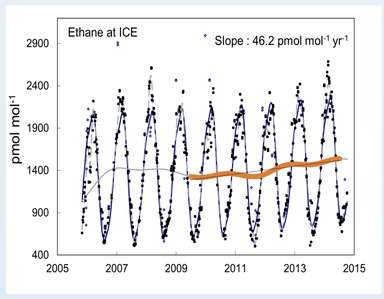


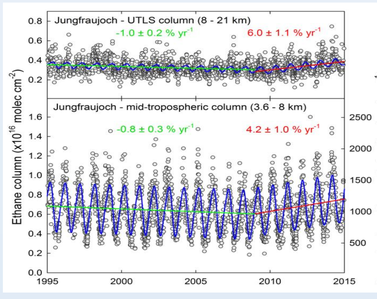


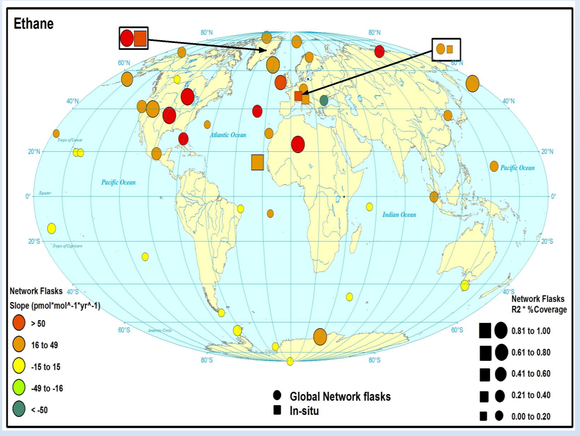
Data quality control is a primary objective of the program. This activity includes the development of standard operational procedures (SOP), data quality objectives, recommendations of measurement techniques, metadata reporting, Central Calibration Laboratories, World Calibration Centres, station audits, coordination of measurements intercomparisons, and data archiving. Data are publicly posted at the Japan Meteorological Agency (http://ds.data.jma.go.jp/gmd/wdcgg/) and the Norwegian Institute for Air Research (http://www.gaw-wdcrg.org/).

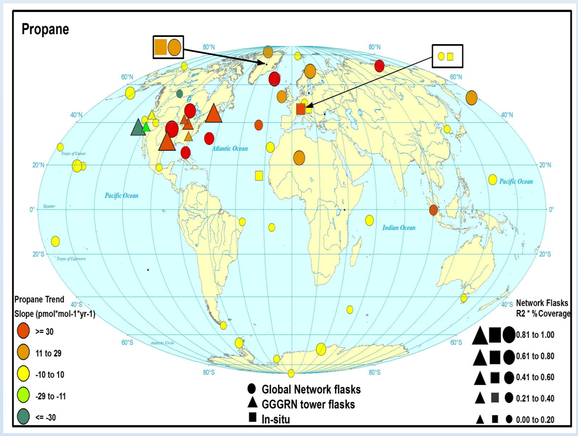
Reversal of Northern Hemisphere Ethane Trend











Observations of the non-methane hydrocarbon (NMHC) ethane from the GAW network have shown a recent, remarkable reversal of the northern hemisphere long-term trend. Ethane, the longest-lived, and at levels of ~0.4 – 2.5 nmol mol^{-1} (ppbv) the most abundant NMHC in the background atmosphere is released from seepage of fossil carbon deposits, volcanoes, fires, and from human activities, with fossil fuel extraction, distribution, and industrial use being the major sources. Pre-industrial ethane atmospheric molar ratios measured in ice cores were ~1/3 of current levels, i.e. ~420 pmol mol^{-1} in the northern hemisphere (NH), and ~100 pmol mol^{-1} in the southern hemisphere (SH). Firn air records show that ethane increased steadily post-1950 and reached a maximum that was ~50% above 1950 levels during 1970–1985. The ethane peak was followed by a downward trend for the next four decades, due to reduced emissions from oil and gas industries and stricter air quality emission controls. The trend of declining global ethane halted between 2005-2010 in most of the NH, and has since reversed. This is evident in several data products, including column observations at Network for the Detection of Atmospheric Composition Change (NDACC; www.ndacc.org) FTIR sites, such as at Jungfraujoch, in VOC data from in-situ monitoring, and in data from the NOAA Global Greenhouse Gas Reference Network (http://instaar.colorado.edu/arl/Global_VOC. html).

The largest ethane increases (5-9% yr^{-1}), are seen in North America and the downwind North Atlantic Region. The average rate of increase across the NH from 2009 – 2014 is between 3-5 % yr^{-1}. Data for the shorter-lived propane allow to more narrowly define the primary source regions of increased emissions. For propane, growth rates of 8-22% yr^{-1} are seen in the central and eastern USA. A surge in oil and gas production has occurred in recent years in these regions. Associated emissions have been shown to result in elevated atmospheric NMHC, ozone production, and deteriorated regional air quality. The geographical distribution of observed ethane and propane provides compelling evidence that their observed NH increases likely stem from the growth of oil and natural gas development. We calculate a top down increase of ethane emissions in the NH of 2.1 ± 1.0 Tg yr^{-1} between 2009.5 – 2014.5. By including other co-emitted oil and natural gas NMHC we estimate a total NMHC emission rate increase of 5.9 ± 4.0 Tg yr^{-1} between 2009.5 – 2014.5. Using ethane/ methane emission ratios from oil and natural gas source regions we estimate an associated increase of methane emission of 22 ± 15 Tg yr^{-1} 2009.5 – 2014.5), representing a ~6.6% increase in the global anthropogenic methane emission over this period. The ability to identify the regions driving these emission changes is hampered by sparse regional network coverage, particularly by the scarcity of observations in Asia and Africa.